

APPENDIX IV E3P REMEDIATION/ VALIDATION CRITERIA

HUMAN HEALTH REMEDIATION TARGETS – LOW-RISE RESIDENTIAL END USE

DETERMINANT	UNITS	WITHIN COVER SYSTEM 700MM (GARDEN)	HARD STANDING AND BENEATH 700MM COVER	PUBLIC OPEN SPACE 700 mm COVER	PUBLIC OPEN SPACE > 600 mm & BENEATH HARDSTAND >1000MM	PATH-WAY
Arsenic	mg/kg	37 ⁽ⁱ⁾	40 ⁽ⁱⁱ⁾	79 ⁽ⁱⁱⁱ⁾	640 ^(iv)	1
Cadmium	mg/kg	11 ⁽ⁱ⁾	85 ⁽ⁱⁱⁱ⁾	120 ⁽ⁱⁱⁱ⁾	532 ^(iv)	1
Chromium (Hexavalent)	mg/kg	6 ⁽ⁱ⁾	6 ⁽ⁱⁱ⁾	7.7 ⁽ⁱⁱⁱ⁾	220 ^(iv)	1
Lead	mg/kg	210 ^(vi)	330 ^(vii)	760 ^(viii)	760 ^(viii)	1
Elemental Mercury	mg/kg	1.2 ⁽ⁱ⁾	1.2 ⁽ⁱⁱ⁾	16 ⁽ⁱⁱⁱ⁾	30 ^(iv)	2
Nickel	mg/kg	180 ⁽ⁱ⁾	180 ⁽ⁱⁱ⁾	230 ⁽ⁱⁱⁱ⁾	3400 ^(iv)	1
Selenium	mg/kg	250 ⁽ⁱ⁾	430 ⁽ⁱⁱ⁾	1100 ⁽ⁱⁱⁱ⁾	1800 ^(iv)	1
Copper	mg/kg	2400 ⁽ⁱ⁾	7100 ⁽ⁱⁱ⁾	12,000 ⁽ⁱⁱⁱ⁾	44,000 ^(iv)	1
Total Cyanide	mg/kg	791	791	791	791	1
Zinc	mg/kg	3700 ⁽ⁱ⁾	40,000 ⁽ⁱⁱ⁾	81,000 ⁽ⁱⁱⁱ⁾	170,000 ^(iv)	1
Phenol	mg/kg	280 ^{(i)(xi)}	280 ^{(xiv)(xi)}	760 ^{(iii)(xi)}	760 ^{(iv)(xi)}	2
Naphthalene	mg/kg	2.3 ^{(i)(xi)}	2.3 ^{(xiv)(xi)}	1200 ^{(iv)(xi)}	1200 ^{(iv)(xi)}	2
Acenaphthylene	mg/kg	170 ^{(i)(xi)}	500 ^(v)	15,000 ^{(iii)(xi)}	29,000 ^{(iv)(xi)}	3
Acenaphthene	mg/kg	210 ^{(i)(xi)}	500 ^(v)	15,000 ^{(iii)(xi)}	29,000 ^{(iv)(xi)}	1
Fluorene	mg/kg	170 ^{(i)(xi)}	500 ^(v)	9900 ^{(iii)(xi)}	20,000 ^{(iv)(xi)}	1
Phenanthrene	mg/kg	95 ^{(i)(xi)}	500 ^(v)	3100 ^{(iii)(xi)}	6200 ^{(iv)(xi)}	3
Anthracene	mg/kg	500 ^{(i)(xi)}	500 ^(v)	74,000 ^{(iii)(xi)}	150,000 ^{(iv)(xi)}	3
Fluoranthene	mg/kg	280 ^{(i)(xi)}	500 ^(v)	3100 ^{(iii)(xi)}	6300 ^{(iv)(xi)}	3
Pyrene	mg/kg	500 ^{(i)(xi)}	500 ^(v)	7400 ^{(iii)(xi)}	15,000 ^{(iv)(xi)}	3
Benzo(a)Anthracene	mg/kg	7.2 ^{(i)(xi)}	11 ^{(ii)(xi)}	29 ^{(iii)(xi)}	49 ^{(iv)(xi)}	3
Chrysene	mg/kg	15 ^{(i)(xi)}	30 ^{(ii)(xi)}	57 ^{(iii)(xi)}	93 ^{(iv)(xi)}	3
Benzo(b)Fluoranthene	mg/kg	2.6 ^{(i)(xi)}	3.9 ^{(ii)(xi)}	7.1 ^{(iii)(xi)}	13 ^{(iv)(xi)}	3
Benzo(k)Fluoranthene	mg/kg	77 ^{(i)(xi)}	110 ^{(ii)(xi)}	190 ^{(iii)(xi)}	370 ^{(iv)(xi)}	3
Benzo(a)Pyrene	mg/kg	2.2 ^{(i)(xi)}	3.2 ^{(ii)(xi)}	5.7 ^{(iii)(xi)}	11 ^{(iv)(xi)}	3
Indeno(123-cd)Pyrene	mg/kg	27 ^{(i)(xi)}	45 ^{(ii)(xi)}	82 ^{(iii)(xi)}	150 ^{(iv)(xi)}	3
Dibenzo(a,h)Anthracene	mg/kg	0.24 ^{(i)(xi)}	0.31 ^{(ii)(xi)}	0.57 ^{(iii)(xi)}	1.1 ^{(iv)(xi)}	3
Benzo(ghi)Perylene	mg/kg	320 ^{(i)(xi)}	360 ^{(ii)(xi)}	640 ^{(iii)(xi)}	1400 ^{(iv)(xi)}	3
TPH C ₅ -C ₆ (aliphatic)	mg/kg	42 ^{(i)(xi)}	42 ^{(ii)(xi)}	42 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₆ -C ₈ (aliphatic)	mg/kg	100 ^{(i)(xi)}	100 ^{(ii)(xi)}	100 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₈ -C ₁₀ (aliphatic)	mg/kg	27 ^{(i)(xi)}	27 ^{(ii)(xi)}	27 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₁₀ -C ₁₂ (aliphatic)	mg/kg	130 ^{(i)(xi)}	130 ^{(ii)(xi)}	130 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₁₂ -C ₁₆ (aliphatic)	mg/kg	1000 ^{(xiv)(xi)}	1000 ^{(xiv)(xi)}	1000 ^{(xiv)(xi)}	10,000 ^{(xiv)(xi)}	1
TPH C ₁₆ -C ₂₁ (aliphatic)	mg/kg	1000 ^{(xiv)(xi)}	1000 ^{(xiv)(xi)}	1000 ^{(xiv)(xi)}	10,000 ^{(xiv)(xi)}	1
TPH C ₂₁ -C ₃₅ (aliphatic)	mg/kg					1
TPH C ₅ -C ₇ (aromatic)	mg/kg	70 ^{(i)(xi)}	370 ^{(ii)(xi)}	370 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₇ -C ₈ (aromatic)	mg/kg	130 ^{(i)(xi)}	860 ^{(ii)(xi)}	860 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₈ -C ₁₀ (aromatic)	mg/kg	34 ^{(i)(xi)}	47 ^{(ii)(xi)}	47 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2
TPH C ₁₀ -C ₁₂ (aromatic)	mg/kg	74 ^{(i)(xi)}	250 ^{(ii)(xi)}	250 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	2



Manox**Detailed Remediation and Enabling Works Strategy**
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TPH C₁₂-C₁₆ (aromatic)	mg/kg	140 ^{(i)(xi)}	1800 ^{(ii)(xi)}	1800 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	1
TPH C₁₆-C₂₁ (aromatic)	mg/kg	260 ^{(i)(xi)}	1900 ^{(ii)(xi)}	1900 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	1
TPH C₂₁-C₃₅ (aromatic)	mg/kg	1000 ^{(xiv)(xi)}	1900 ^{(ii)(xi)}	1900 ^{(ii)(xi)}	10,000 ^{(xiv)(xi)}	1
Asbestos	Fibres Volume Weight (%)	NFD	0.001%	NFD	0.1%	4

Notes 1

NFD = No Fibres Detected

Asbestos will be screened visually on site by a qualified environmental consultant and where potential ACM is identified, representative samples will be subject to quantitative analysis of % volume by weight.

Should any ACM be identified within the soil matrices, further detailed % assessment would be required when the reported laboratory result exceeds the limit of detection for the analytical method at 0.01% by volume (weight).

Notes 2

Excludes matrices where free product is observed.

No viable exposure pathway beneath hardstanding and cover system.

Notes 3

Main exposure pathways: 1 = soil ingestion, 2 = vapour inhalation (indoor), 3 = dermal contact and ingestion, 4 = dust inhalation.

Abbreviations: GAC = general assessment criteria, n = number of samples, MC = maximum concentration, N/A = Not Applicable (no exceedance of assessment criteria), Loc of MC = location of exceedances.

- i. Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use with plant uptake.
- ii. Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use without plant uptake – these levels used below 600 mm cover system within residential gardens as soils will be present within a residential setting yet soils will not be disturbed and garden plants will not reach these soils.
- iii. Value derived from LQM Suitable 4 Use Levels (S4ULs) for public open space (POS) residential.
- iv. Value derived from LQM Suitable 4 Use Levels (S4ULs) for public open space (POS) park – these levels used below 300 mm POS cover system as soils will not be disturbed by any future site users and exposure to these soils will be similar to a park end use.
- v. Value derived from LQM Suitable 4 Use Levels (S4ULs) alongside assessment with WM3 to ensure that materials remaining on site do not exceed the WM3 toxicity criteria for hazardous waste.
- vi. Value derived from Category 4 Screening Levels (C4SL) for residential land use with homegrown produce.
- vii. Value derived from Category 4 Screening Levels (C4SL) for residential land use without homegrown produce.
- viii. Value derived from Category 4 Screening Levels (C4SL) for public open space (POS) residential.
- ix. Value derived from Category 4 Screening Levels (C4SL) for public open space (POS) park.
- x. Mercury – based on elemental mercury.
- xi. PAH and TPH levels used are for 1% SOM.
- xii. Xylenes based on p-xylene (o-xylene 2600 mg/kg, m-xylene 3500 mg/kg) and is capped by its solubility.
- xiii. Value derived from LQM Suitable 4 Use Levels (S4ULs) for residential end use with plant uptake due to the volatilisation risk.
- xiv. BTEX is not SOM-related due to inhalation pathway.



APPENDIX V

E3P MATERIAL IMPORT CRITERIA

SITE OF IMPORTATION ADDRESS		E3P TAYLOR ROAD MANCHESTER, M41 7JQ +44 (0) 161 707 9612 info@e3p.co.uk	
Client			
Main Contractor			
Earthworks Contractor			
Haulier			
Date of Planned Import			
Overview of Planned Material Import			
Material Source (Site of Origin) and Postcode			
Site Investigation Report	Report Title and Reference: Date: Information Supplied By:		
Reason for Generation of Excess Material at Site of Origin			
Chemical Test Results for Stockpile at Site of Origin	Date: Laboratory Certificate Ref: Organisation Responsible for Stockpile Sampling:		
Geotechnical Material Classification and Testing	Delete as Appropriate: Class 1 / Class 2 / Class 6 / Topsoil		
Pictures of Material Stockpile Pending Transportation	Delete as Appropriate: Yes / No		
Person or Organisation Responsible for Ensuring Quality Control at Site of Origin			
Quantity of Material to Be Imported (m³)			
Proposed Area of Deposition (Site of Reuse)			
Waste Exemption/Permit or CL:AIRE MMP	Delete as Appropriate: U1 Standard Rules / CL:AIRE MMP (Direct Transfer) / Bespoke		



APPENDIX VI CONTRACTOR PRE- COMMENCEMENT CHECK SHEET

GEOTECHNICAL ENABLING WORKS PRE-START FORM

Prior to the commencement of any site remediation or enabling works, this form will be completed by E3P, in the presence of the appointed contractor, to ensure that all pertinent remediation and enabling works activities are fully discussed and understood.

Activity	Testing Responsibility	Contractors Method Statement Required (Y/N)	Comment/Action
Deployment of Environmental Permit			Ref No:
Deployment of LAPC Part B – Mobile Plant Permit			Ref No:
CL:AIRE MMP and Qualified Person Declaration			Ref No:
Identification of All Invasive Plant Species and Production of Eradication Plan with Appropriate Supervision by Specialist			Appointed specialist:
Removal of All Vegetation			Note disposal location:
Removal of All Root Bulbs and Root Networks			Note disposal location:
Identification of Contamination Hotspots, Removal of Material and Stockpile			Rationale:
Legislatively Compliant Procedure to Deal with Contamination Excavated from Hotspot			Rationale:
Processing and Recycling of Aggregate with Geotechnical and Chemical Validation Testing			Note stockpile location and anticipated volume:
Stockpiling of Subsoil and Certification of Suitability for Reuse			Stockpile location:
Decommission of All Redundant Drainage Infrastructure			
Decommission of All Former Interceptors			
Decommission of All Former Above- and Below-Ground Tanks			
Removal of All Asbestos to a Licensed Facility			
Engineering of Plots for Shallow Spread Foundation in Accordance with E3P Geotechnical Specification			Plot Numbers
Engineering of Plots for VSC in Accordance with E3P Geotechnical Specification			Plot Numbers.



Activity	Testing Responsibility	Contractors Method Statement Required (Y/N)	Comment/Action
Engineering of Plots for Pile Foundation in Accordance with E3P Geotechnical Specification			Plot Numbers
Engineering of Plots for Raft Foundation in Accordance with E3P Geotechnical Specification			Plot Numbers
Stockpiling of Topsoil and Certification of Suitability for Reuse			Stockpile location
Engineering of Highways Bulk Upfill in Accordance with E3P Specification with Compliant Validation Testing			Upfill specification
Engineering of Highways Subgrade in Accordance with E3P Specification with Compliant Validation Testing			Upfill specification
Engineering of Highways Capping in Accordance with E3P Specification with Compliant Validation Testing			Upfill specification
Cut-and-Fill the Development Site to Clients' Required Elevation with As-Built Survey			Required formation elevations



APPENDIX VII CONTRACTOR COMPLETION CHECK SHEET

GEOTECHNICAL ENABLING WORKS COMPLETION FORM

Upon completion of all site remediation and enabling works, this form will be completed by E3P, in the presence of the appointed contractor, to ensure that all pertinent geotechnical enabling works activities are complete or, where a deviation from the specification has occurred, all future limitations and issues are documented for the client's records.

Activity	Complete			Signature
	Yes	No	N/A	(initial)
Eradication of all invasive plant species				
Removal of all vegetation				
Removal of all root bulbs and root networks				
Stockpiling of topsoil and certification of suitability for reuse				
Stockpiling of subsoil and certification of suitability for reuse				
Stockpile all recycled aggregate with geotechnical and chemical validation testing				
Removal of all relict foundations and infrastructure in their entirety				
Decommission of all redundant drainage infrastructure				
Decommission of all former interceptors				
Decommission of all former above- and below-ground tanks				
Removal of all waste materials to a licensed facility				
Removal of all asbestos to a licensed facility				
Engineering of all plots for shallow spread foundation in accordance with E3P Geotechnical Specification				
Engineering of all plots for VSC in accordance with E3P Geotechnical Specification				
Engineering of all plots for pile foundation in accordance with E3P Geotechnical Specification				
Engineering of all plots for raft foundation in accordance with E3P Geotechnical Specification				
Engineering of highways bulk upfill in accordance with E3P Specification with compliant validation testing				
Engineering of highways subgrade in accordance with E3P Specification with compliant validation testing				
Engineering of highways capping in accordance with E3P Specification with compliant validation testing				
Cut-and-fill the development site to client's required elevation with as-built survey				



POST-REMEDATION AND ENABLING LIMITATIONS

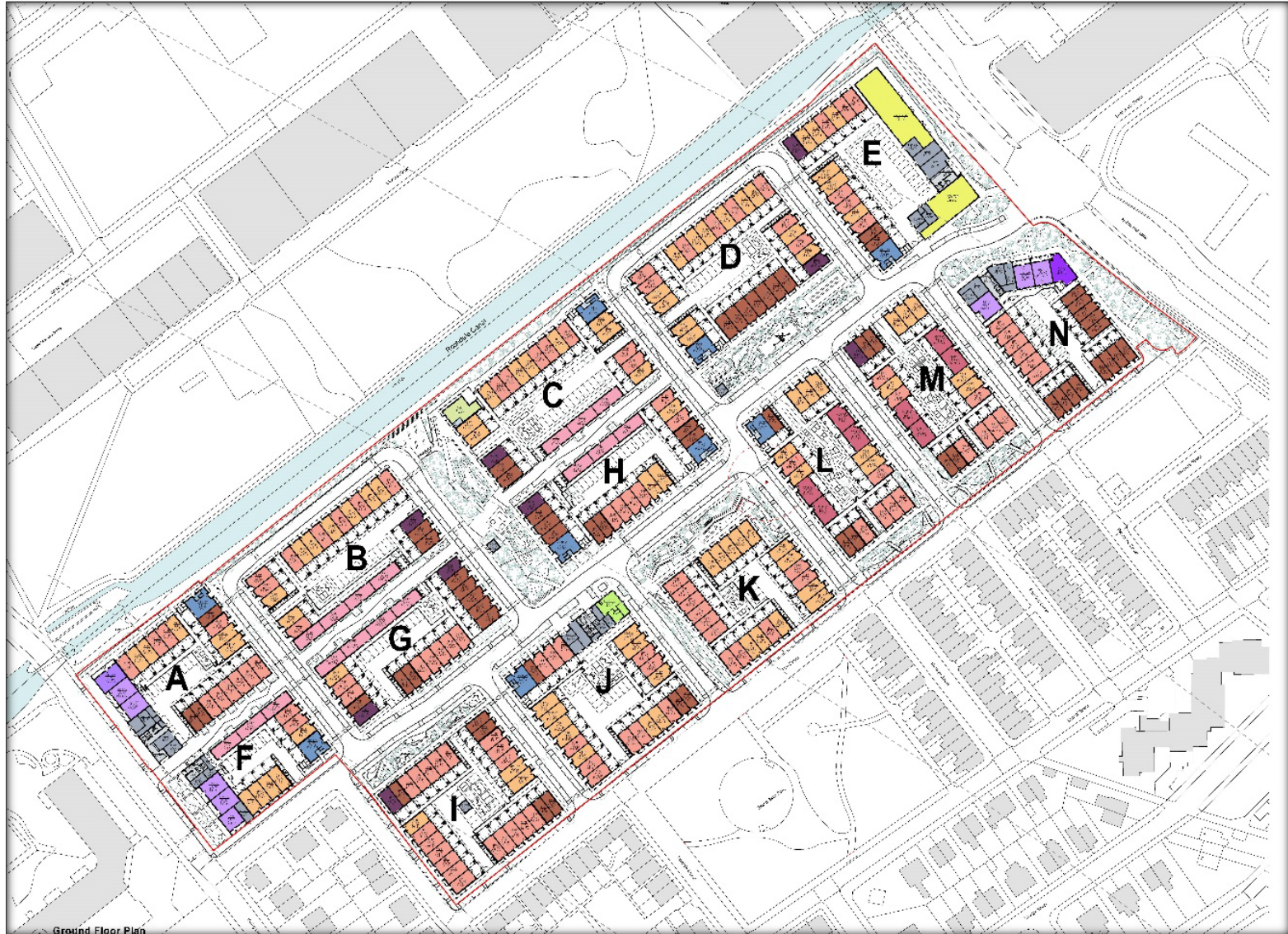
All and every deviation from the approved specification for works should be documented by the remediation and enabling works contractor below.



APPENDIX VIII

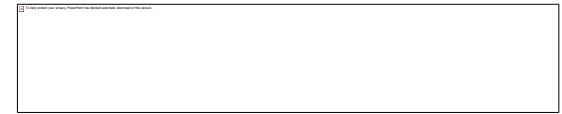
MCAULIFFE DOCUMENTS

Manox Enabling Works – Phasing Proposed Layout



Manox Enabling Works – Phasing

Current T=0 weeks



Manox Enabling Works – Phasing

Current T=0-5 weeks – Site Set up and Clearance



Manox Enabling Works – Phasing

Current T=5-10 weeks – Hot Spot Removal



Manox Enabling Works – Phasing

Current T=9-17 weeks – Mine Working Remediation



Manox Enabling Works – Phasing

Current T=17-26 weeks – Sheet Piling and Earthworks



Manox Enabling Works – Phasing

Current T=27-31 weeks – Remediation and Archaeology.



Manox Enabling Works – Phasing

Current T=32-59 weeks – Remediation and Earthworks



Manox Enabling Works – Phasing

Current T=60-62 weeks – Remediation and Earthworks.



Manox Enabling Works – Phasing

Current T=63-77 weeks – Remediation and Earthworks.



Manox Enabling Works – Phasing

Current T=78 weeks – Remediation and Earthworks.



Hotspot Location Plan



McAuliffe Civil Engineering Limited

Stabilisation/Solidification Treatability Report

Job No:	MC2906
Job Name:	Manox Site
Report No:	MC2906 Manox S/S Treatability
Client:	Engie
Site Address:	Land north of Coleshill Street, Miles Platting, Manchester, M40 7LE
Date:	July 2022

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<i>Appendix B:</i>	Laboratory Test Report Certificates
<i>Appendix C:</i>	References

1 Introduction

McAuliffe were instructed by Engie to undertake stabilisation/solidification treatability works on contaminated soils present on the Manox site, north of Coleshill Street, Miles Platting, Manchester. This report details the works done and presents the results of leachability testing carried out on samples of each trial mix. It concludes with a discussion on the relative performance of the various mixes considering the full-scale treatment works required to be carried out on the soils at the site.

2 Stabilisation/Solidification Technique

In the UK S/S techniques are well established for ground treatment of multiple contaminants. The process is an enhanced approach that has been applied to a broad range of contaminated soils, dredge and other media, contaminated with a wide variety of hazardous substances. At its simplest, the process involves mixing chemicals, reagents and binding agents into the contaminated media in order to change and immobilise the contaminants within the material. The resulting chemical reactions and physical changes chemically fix the contaminants, so removing the risks to human health and the wider environment.

The ability to treat multiple contaminant types within the same media is a key benefit of the S/S process, as it means it can be used in complex contamination situations such as are found when treating heavy industrial, coke and town gas sites. Experience has shown that chemical and physical test results from laboratory-scale studies provide a good indication of the expected performance in the full-scale works.

3 Treatability Study

Bulk soil samples of contaminated soils were taken from trial pits excavated at the site, at locations in the most heavily impacted areas, particularly around the tar channel location, for use in the trials by E3P. A plan of their locations is included in Appendix A. It should be noted that, based on the data obtained from previous site investigations, these samples do not represent the majority of the soils potentially requiring across the site, but a worst case scenario, probably amounting to only around 4% of the total treatment volume.

Total concentration and leachate analyses were carried out on the various samples taken, with laboratory certificates presented in Appendix B. The summarised results from the samples used in the treatability works are presented in Tables 1a and b. Batch leachate testing was carried out using BS EN12457 Part 2, with a liquid to solids ratio of 10:1, as this represents worst case environmental stress scenarios.

Preparation of S/S samples for leachate testing does not require drying, as particle size reduction and general disaggregation is not impacted by moisture content, due to the nature of stabilised materials.

Sample Reference		TP803	TP807	TP810	TP813	TP814	TP816
Analytical Parameter (Soil Analysis)	Unit						
Stone Content	%	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Moisture Content	%	27	19	16	18	8.0	9.3
Total mass of sample received	kg	0.40	0.50	0.50	1.2	0.60	0.50
General Inorganics							
pH - Manual	pH Units	-	8.2	8.6	7.1	8.0	
pH - Automated	pH Units	-	-	-	-	-	
Total Cyanide	mg/kg	840	5000	1200	2800	9500	8.6
Complex Cyanide	mg/kg						8.6
Free Cyanide	mg/kg						< 1.0
Total Sulphate as SO4	mg/kg		5100	3900	31000	140000	
Water Soluble SO4 (2:1 Leach. Equiv.) 1hr extraction	g/l	-	1.7	0.33	1.8	3.0	
Water Soluble SO4 (2:1 Leach. Equiv.) 1hr extraction	mg/kg	-	3400	660	3700	6100	
Water Soluble SO4 (2:1 Leach. Equiv.) 1hr extraction	mg/l	-	1700	328	1830	3050	
Sulphide	mg/kg	-	410	5.8	100	220	
Total Sulphur	mg/kg	-	26000	2100	23000	55000	
Total Organic Carbon (TOC)	%	2.6	3.7	1.7	-	5.0	
Total Organic Carbon (TOC)	%	-	-	-	8.7	-	
Total Phenols							
Total Phenols (monohydric)	mg/kg	-	< 1.0	< 1.0	210	7.9	< 1.0
Speciated PAHs							
Naphthalene	mg/kg	1.8	-	0.33	2900	-	< 0.05
Acenaphthylene	mg/kg	< 0.05	-	< 0.05	< 0.05	-	< 0.05
Acenaphthene	mg/kg	2.9	-	0.20	180	-	< 0.05
Fluorene	mg/kg	2.2	-	< 0.05	200	-	< 0.05
Phenanthrene	mg/kg	7.1	-	0.84	370	-	< 0.05
Anthracene	mg/kg	1.3	-	< 0.05	83	-	< 0.05
Fluoranthene	mg/kg	3.8	-	0.87	130	-	< 0.05
Pyrene	mg/kg	3.4	-	0.85	98	-	< 0.05
Benzo(a)anthracene	mg/kg	1.7	-	0.68	31	-	< 0.05
Chrysene	mg/kg	1.6	-	0.58	23	-	< 0.05
Benzo(b)fluoranthene	mg/kg	1.2	-	0.61	15	-	< 0.05
Benzo(k)fluoranthene	mg/kg	0.77	-	0.51	7.5	-	< 0.05
Benzo(a)pyrene	mg/kg	1.4	-	0.70	9.8	-	< 0.05
Indeno(1,2,3-cd)pyrene	mg/kg	0.56	-	0.45	6.5	-	< 0.05
Dibenz(a,h)anthracene	mg/kg	0.21	-	< 0.05	2.7	-	< 0.05
Benzo(ghi)perylene	mg/kg	0.81	-	0.60	7.1	-	< 0.05
Total PAH							
Speciated Total EPA-16 PAHs	mg/kg	30.7	-	7.22	4070	-	< 0.80
Heavy Metals / Metalloids							
Arsenic (aqua regia extractable)	mg/kg	68	3600	73	98	45	6.7
Barium (aqua regia extractable)	mg/kg	180	-	-	-	-	
Beryllium (aqua regia extractable)	mg/kg	2.6	-	-	-	-	
Boron (water soluble)	mg/kg	0.9	-	-	-	-	
Chromium (III)	mg/kg						19
Chromium (aqua regia extractable)	mg/kg	-	21	35	40	24	19
Copper (aqua regia extractable)	mg/kg	110	42000	240	210	58	19
Lead (aqua regia extractable)	mg/kg	200	2300	230	760	280	21
Mercury (aqua regia extractable)	mg/kg	1.7	< 0.3	< 0.3	1.5	0.9	< 0.3
Nickel (aqua regia extractable)	mg/kg	46	29	49	16	9.5	17
Selenium (aqua regia extractable)	mg/kg	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Vanadium (aqua regia extractable)	mg/kg	73	-	-	-	-	
Zinc (aqua regia extractable)	mg/kg	140	560	440	130	120	42
Monoaromatics & Oxygenates							
Benzene	µg/kg	-	< 1.0	-	-	220	< 1.0
Toluene	µg/kg	-	< 1.0	-	-	210	< 1.0
Ethylbenzene	µg/kg	-	< 1.0	-	-	230	< 1.0
p & m-xylene	µg/kg	-	< 1.0	-	-	470	< 1.0
o-xylene	µg/kg	-	< 1.0	-	-	650	< 1.0
MTBE (Methyl Tertiary Butyl Ether)	µg/kg	-	< 1.0	-	-	< 1.0	< 1.0
Petroleum Hydrocarbons							
TPH-CWG - Aliphatic >EC10 - EC12	mg/kg	-	< 1.0	-	-	180	< 1.0
TPH-CWG - Aliphatic >EC12 - EC16	mg/kg	-	7.8	-	-	240	< 2.0
TPH-CWG - Aliphatic >EC16 - EC21	mg/kg	-	30	-	-	98	< 8.0
TPH-CWG - Aliphatic >EC21 - EC35	mg/kg	-	70	-	-	130	< 8.0

TPH-CWG - Aliphatic >EC35 - EC40 EH_CU_1D_AL	mg/kg						< 10
TPH-CWG - Aliphatic (EC5 - EC35)	mg/kg	-	110	-	-	650	
TPH-CWG - Aromatic >EC5 - EC7	mg/kg	-	< 0.001	-	-	0.22	< 0.001
TPH-CWG - Aromatic >EC7 - EC8	mg/kg	-	< 0.001	-	-	0.21	< 0.001
TPH-CWG - Aromatic >EC8 - EC10	mg/kg	-	< 0.001	-	-	11	< 0.001
TPH-CWG - Aromatic >EC10 - EC12	mg/kg	-	4.4	-	-	600	< 1.0
TPH-CWG - Aromatic >EC12 - EC16	mg/kg	-	31	-	-	2700	< 2.0
TPH-CWG - Aromatic >EC16 - EC21	mg/kg	-	100	-	-	1800	< 10
TPH-CWG - Aromatic >EC21 - EC35	mg/kg	-	120	-	-	630	< 10
TPH-CWG - Aromatic >EC35 - EC40 EH_CU_1D_AR	mg/kg						< 10
TPH-CWG - Aromatic (EC5 - EC35)	mg/kg	-	250	-	-	5800	
TPH Total C5 - C40 EH_CU+HS_1D_TOTAL	mg/kg						< 10
TPH (C5 - C6)	mg/kg	< 1.0	-	< 1.0	79	-	
TPH (C6 - C8)	mg/kg	< 0.1	-	< 0.1	130	-	
TPH (C8 - C10)	mg/kg	< 0.1	-	< 0.1	300	-	
TPH (C10 - C12)	mg/kg	4.8	-	2.1	6300	-	
TPH (C12 - C16)	mg/kg	16	-	11	4000	-	
TPH (C16 - C21)	mg/kg	20	-	33	3900	-	
TPH (C21 - C35)	mg/kg	34	-	120	2400	-	
TPH (C35 - C40)	mg/kg	16	-	27	110	-	
TPH Total C5 - C40	mg/kg	90	-	190	17000	-	
VOCs							
Isopropylbenzene	µg/kg	-	< 1.0	-	-	55	< 1.0
1,3,5-Trimethylbenzene	µg/kg	-	< 1.0	-	-	1700	< 1.0
1,2,4-Trimethylbenzene	µg/kg	-	< 1.0	-	-	8300	< 1.0
p-Isopropyltoluene	µg/kg	-	< 1.0	-	-	460	< 1.0
SVOCs							
Aniline	mg/kg	-	< 0.1	-	-	9.4	< 0.1
2-Methylnaphthalene	mg/kg	-	3.8	-	-	440	< 0.1
Acenaphthylene	mg/kg	-	0.29	-	-	< 0.05	< 0.05
Acenaphthene	mg/kg	-	17	-	-	630	< 0.05
2,4-Dinitrotoluene	mg/kg	-	< 0.2	-	-	< 0.2	< 0.2
Dibenzofuran	mg/kg	-	6.6	-	-	620	< 0.2
Fluorene	mg/kg	-	9.6	-	-	500	< 0.05
Phenanthrene	mg/kg	-	21	-	-	1200	< 0.05
Anthracene	mg/kg	-	4.8	-	-	300	< 0.05
Carbazole	mg/kg	-	< 0.3	-	-	70	< 0.3
Anthraquinone	mg/kg	-	< 0.3	-	-	39	< 0.3
Fluoranthene	mg/kg	-	20	-	-	310	< 0.05
Pyrene	mg/kg	-	17	-	-	210	< 0.05
Benzo(a)anthracene	mg/kg	-	5.6	-	-	34	< 0.05
Chrysene	mg/kg	-	5.3	-	-	31	< 0.05
Benzo(b)fluoranthene	mg/kg	-	5.5	-	-	11	< 0.05
Benzo(k)fluoranthene	mg/kg	-	5.9	-	-	3.5	< 0.05
Benzo(a)pyrene	mg/kg	-	3.0	-	-	5.3	< 0.05
Indeno(1,2,3-cd)pyrene	mg/kg	-	1.3	-	-	2.5	< 0.05
Dibenz(a,h)anthracene	mg/kg	-	0.44	-	-	< 0.05	< 0.05
Benzo(ghi)perylene	mg/kg	-	2.0	-	-	3.0	< 0.05

Table 1a. Baseline Soils Solids Results
(Only determinants with any results above LoD presented)

Sample Reference		TP813	TP816	TP814
Analytical Parameter (Leachate Analysis)	Units			
General Inorganics				
pH	pH Units	7.5		
Total Cyanide (Low Level 1 µg/l)	µg/l	17000	340	11000
Complex Cyanide (Low Level)	µg/l		330	10000
Free Cyanide (Low Level 1 µg/l)	µg/l		8	500
Total Phenols				
Total Phenols (monohydric)	µg/l	3000	4.7	67
Speciated PAHs				
Naphthalene	µg/l	3100	< 0.01	< 0.01
Acenaphthylene	µg/l	1.2	< 0.01	4.3
Acenaphthene	µg/l	12	< 0.01	180
Fluorene	µg/l	5.9	< 0.01	53
Fluoranthene	µg/l	< 0.01	< 0.01	3.9
Pyrene	µg/l	< 0.01	< 0.01	1.6
Total PAH				
Total EPA-16 PAHs	µg/l	3200	< 0.2	240
Heavy Metals / Metalloids				
Arsenic (dissolved)	µg/l	16	8.5	9.3
Cadmium (dissolved)	µg/l	< 0.08	0.26	0.21
Chromium (hexavalent)	µg/l	< 5.0	< 5.0	< 5.0
Chromium (III)	µg/l		< 5.0	< 5.0
Chromium (dissolved)	µg/l	1.0	1.9	1.1
Copper (dissolved)	µg/l	18	7.1	< 0.7
Lead (dissolved)	µg/l	4.4	10	6.5
Mercury (dissolved)	µg/l	< 0.5	< 0.5	< 0.5
Nickel (dissolved)	µg/l	2.6	5.0	2.6
Selenium (dissolved)	µg/l	< 4.0	< 4.0	< 4.0
Zinc (dissolved)	µg/l	4.8	8.6	3.8
Monoaromatics & Oxygenates				
Benzene	µg/l	7500	< 1.0	< 1.0
Toluene	µg/l	11000	< 1.0	< 1.0
Ethylbenzene	µg/l	780	< 1.0	< 1.0
p & m-xylene	µg/l	5300	< 1.0	< 1.0
o-xylene	µg/l	2400	< 1.0	< 1.0
MTBE (Methyl Tertiary Butyl Ether)	µg/l	< 10	< 10	< 10
Petroleum Hydrocarbons				
TPH1 (C10 - C40)	µg/l	7200		
TPH-CWG - Aromatic >C5 - C7	µg/l	7500	< 1.0	< 1.0

TPH-CWG - Aromatic >C7 - C8	µg/l	11000	< 1.0	< 1.0
TPH-CWG - Aromatic >C8 - C10	µg/l	9100	< 1.0	23
TPH-CWG - Aromatic >C10 - C12	µg/l	4100	< 10	640
TPH-CWG - Aromatic >C12 - C16	µg/l	2700	< 10	400
TPH-CWG - Aromatic >C16 - C21	µg/l	320	< 10	130
TPH-CWG - Aromatic (C5 - C35)	µg/l	35000		
TPH Total C5 - C40 EH+HS_1D_TOTAL_#1_#2_MS	µg/l		< 10	1200
VOCs				
1,3,5-Trimethylbenzene	µg/l		< 1.0	7.4
1,2,4-Trimethylbenzene	µg/l		< 1.0	16
SVOCs				
Aniline	µg/l		< 0.05	21
2,4-Dimethylphenol	µg/l		< 0.05	23
Acenaphthylene	µg/l		< 0.01	4.3
Acenaphthene	µg/l		< 0.01	180
Dibenzofuran	µg/l		< 0.05	110
Fluorene	µg/l		< 0.01	53
Carbazole	µg/l		< 0.05	40
Anthraquinone	µg/l		< 0.05	49
Fluoranthene	µg/l		< 0.01	3.9
Pyrene	µg/l		< 0.01	1.6

Table 1b. Baseline Soils Batch Leachate Results
(Only determinants with any results above LoD presented)

Treatment mixes selected were based on those that have been successful in targeting similar contaminants and soil types on previous projects. A total of 21 different base-mixes were used, incorporating various combinations of Ordinary Portland cement (OPC), quicklime (QL), granulated ground blast furnace slag (GGBS), bentonite and granular activated carbon (GAC), together with an alkaline oxidation step included for some of the high Cyanide impacted material mixes. This was done using Sodium Hypochlorite (NaOCl) (15% solution) and Sodium Hydroxide (NaOH) (20% solution) as an initial pre-treatment stage, before the addition of other additives. Some particle size reduction was undertaken on the source soils, with material greater than 15mm being removed. This was to ensure that the materials were comparable with the 500g 80mm x 110mm plastic sample tubs used for batch leachate testing and the 60mm x 70mm plastic sample tubes used for the tank tests.

Due to the potential for relatively high localised variability of contaminant concentrations to be present, as identified from previous investigations, two main composites of the samples were produced for the trial, based on the results from the baseline testing. One with a lower Cyanide (CN) concentration (although still relatively high – combining samples from TP803, TP810 and TP816 – visually characterised as a *very cohesive clay material*), the other with a very high CN concentration (combining samples from TP807, TP813 and TP814 – visually characterised as a *dark/black sticky clay with very strong hydrocarbon odour*).

The composite soils were mixed with various admixture formulations and at varying addition rates, using water to binder ratios of 0.3 to 0.5, to form homogenous mixes and then each mix placed into two sample containers as detailed above, one for the batch test and the other for the tank test and left to cure/hydrate in a high humidity environment until required for testing. Table 2 shows the composition of each of the mixes used in the study.

						LOW CN MIXES									HIGH CN MIXES			LOW CN MIXES		HIGH CN MIXES	
Mix No.	1	2	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Mass in g																					
Soil	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900	900
OPC	27	18.9	18	22.5	22.1	17.2	27	31.9	34.4	30	30	19.6	27	24.5	27	27	27	30	21.6	27	24.9
Quicklime				22.5	22.2	11.5			22.9			13.1	27	16.5	16.5	27	36			9.8	8.3
Bentonite	18	12.6	18					21.37													
GGBS	45	31.5	36	45	27.7	34.4	54	63.8	68.7	60	60	39.3	54	49	54	54	54	50	36	54	49.9
NaOH (20%)											25	16		25.3	37.5	50.6					
NaOH (25%)																	60.8				
NaOCL										46.7	45.5	30		47	70.5	94	141				
GAC																		10	14.4	18	24.9
water	16.4	18.9	21.6	36	28.8	25.3	24.3	40.9	63	45	45	29	32.4	27	0	0		24	17.3	27.2	25
25% QL soln										20											
% binder addition																					
OPC	3	2.1	2	2.5	2.5	1.9	3	3.5	3.8	3.3	3.3	2.2	3	2.7	3	3	3	3.3	2.4	3	2.76
Quicklime				2.5	2.5	1.3			2.5			1.5	3	1.8	2	3	4			1	0.92
Bentonite	2	1.4	2					2.4													
GGBS	5	3.5	4	5	3	3.8	6	7.1	7.6	6.6	6.6	4.4	6	5.4	6	6	6	5.5	4	6	5.4
GAC																		1.1	1.6	2	2.76
total % binder addition	10	7	8	10	8	7	9	13	14	10	10	8	12	10	11	12	13	10	8	12	12
water/binder (w/b)	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.35	0.5	0.5	0.5	0.4	0.3	0.3	0	0	0	0.3	0.3	0.3	0.3

Table 2. S/S Mix Designs used in the Treatability Work

4 Results – Brief Outline Summary

Summarised batch leachate results for each of the different mix designs are shown in Tables 3a and b. Summarised tank test results for Mixes 5 and 14 are shown in Tables 4a and b, respectively.

Lower CN impacted soils mixes

The initial mixes that incorporated bentonite were particularly poor at fixing CN. However, when replaced with 2.5% QL there was a significant reduction in CN leachability. With a reduction in QL and overall binder addition, the CN leachability again increased. An increase in addition rate of both GGBS and QL (Mix 10) had a marked improvement in reducing the leachate concentrations of both CN and SO₄. Of note is the reduction in PAH leachability with the higher addition rate of bentonite in Mix 9, which is also evident with Mixes 19 and 20 with inclusion of relatively small quantities of GAC.

OPC and pozzolanic waste forms rely heavily on pH control for metal containment. Normally a high pH is desirable as metal hydroxides have minimum solubility in the range of between 7.5 - 11. However, some metals such as Cr, Cu and Ni can exhibit amphoteric behaviour, having higher solubilities at both high and low pH, with the lowest at around pH 9 - 10. This is generally demonstrated in the results for the metals leachability. It can be seen that Arsenic is fixed more strongly with a combination of GGBS and QL in the binder.

The additional of the alkaline oxidation step (Mixes 11 & 12) did not generally have any beneficial effects on reducing leachability.

Higher CN impacted soils mixes

High levels of CN are generally very difficult to stabilise and fix, especially with hydraulic binder systems. It has a tendency to slow down their reactivity and if the cyanide content is too high, even kill it. The chemical form of the cyanide also has its importance but on that point the very limited scientific literature that exists does not give any detail.

Notwithstanding the above comments, Mix 14 was chosen to assess the potential performance of a standard hydraulic binder with the very high CN impacted materials. Mixes 15 – 18 incorporated an initial alkaline oxidation step in an attempt reduce the CN levels to a point manageable with the subsequent addition of a hydraulic binder system. The results would tend to suggest that the oxidation approach was ineffective and Mix 14 actually showing the lowest CN leachate concentration, although still well above the baselines. The GAC mixes (Mixes 21 and 22) were not effective against the high CN levels.

Sample Reference		Baseline (TP816)	Mix 1	Mix 2	Mix 3	Mix 4	Mix 5	Mix 6	Mix 7	Mix 9	Mix 10	Mix 11	Mix 12	Mix 13	Mix 19	Mix 20
Analytical Parameter (Leachate Analysis)	Units															
General Inorganics																
pH (automated)	pH Units		11.5	11.4	11.4	12.2	12.4	12.1	11.6	11.7	12.3	11.9	11.8	12.2	11.3	11.1
Total Cyanide (Low Level 1 µg/l)	µg/l	340	10000	14000	18000	160	190	860	3400	2300	18	770	3500	300	6500	9900
Complex Cyanide (Low Level)	µg/l	330	10000	13000	18000	160	190	860	3400	2300	18	760	3500	300	6500	9900
Free Cyanide (Low Level 1 µg/l)	µg/l	8	40	41	55	< 1	< 1	1	5	2	< 1	8	13	< 1	< 1	3
Sulphate as SO ₄	µg/l		66400	74300	105000	23300	24800	36100	116000	68.5	20.6	48.5	54.3	32.1	104	83.7
Total Phenols																
Total Phenols (monohydric)	µg/l	4.7	2.0	1.7	1.9	< 1.0	2.5	< 1.0	2.2	11	11	16	14	16	6.6	7.5
Speciated PAHs																
Naphthalene	µg/l	< 0.01	1.0	1.5	1.8	2.6	1.5	4.7	2.9	< 0.01	5.4	1.7	4.1	1.8	< 0.01	< 0.01
Acenaphthylene	µg/l	< 0.01	< 0.01	< 0.01	0.24	< 0.01	< 0.01	< 0.01	0.42	< 0.01	0.44	< 0.01	0.23	< 0.01	< 0.01	< 0.01
Acenaphthene	µg/l	< 0.01	1.4	1.4	1.5	0.79	1.0	0.90	2.1	< 0.01	2.1	0.29	0.90	0.28	< 0.01	< 0.01
Fluorene	µg/l	< 0.01	0.75	0.71	0.74	0.35	0.65	0.32	1.0	< 0.01	0.82	< 0.01	0.69	0.21	< 0.01	< 0.01
Phenanthrene	µg/l	< 0.01	0.74	0.60	0.59	0.33	0.61	< 0.01	0.69	< 0.01	0.58	< 0.01	0.72	< 0.01	< 0.01	< 0.01
Total PAH																
Total EPA-16 PAHs	µg/l	< 0.2	4.0	4.1	4.8	4.1	3.7	6.0	7.1	< 0.2	9.3	2.0	6.6	2.3	< 0.2	< 0.2
Heavy Metals / Metalloids																
Arsenic (dissolved)	µg/l	8.5	6.8	7.8	7.1	1.8	1.8	< 1.0	3.7	5.5	1.0	< 1.0	5.4	< 1.0	12	12
Chromium (hexavalent)	µg/l	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
Chromium (III)	µg/l	< 5.0	6.4	5.8	< 5.0	7.5	10	6.9	< 5.0	< 5.0	< 5.0	12	< 5.0	< 5.0	8.7	5.3
Chromium (dissolved)	µg/l	1.9	6.4	5.8	3.9	7.5	10	6.9	3.0	3.5	2.5	12	4.1	4.1	8.7	5.3
Copper (dissolved)	µg/l	7.1	43	28	68	29	150	33	20	28	16	11	21	34	22	12
Lead (dissolved)	µg/l	10	1.9	2.4	4.3	2.4	1.6	3.3	3.5	3.9	1.2	2.4	4.0	3.6	3.2	3.1
Mercury (dissolved)	µg/l	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Nickel (dissolved)	µg/l	5.0	19	9.9	18	9.8	39	13	9.4	11	9.2	6.2	5.4	23	3.8	3.7
Selenium (dissolved)	µg/l	< 4.0	11	7.7	9.5	< 4.0	< 4.0	< 4.0	< 4.0	9.4	< 4.0	12	< 4.0	14	8.1	< 4.0
Zinc (dissolved)	µg/l	8.6	4.1	4.0	1.8	7.2	5.4	4.4	2.6	7.8	7.3	6.5	7.8	4.7	3.3	4
Monoaromatics & Oxygenates																
Petroleum Hydrocarbons																
VOCs																
Trichloromethane	µg/l	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	390	140	< 1.0	< 1.0
SVOCs																

Table 3a: Summary of S/S Trial Batch Leachability Results (lower CN impacted soil mixes)
(Only determinants with any results above LoD presented)

above
baseline

[illegible]

TPH-CWG - Aromatic >C8 - C10 _{HS_1D_AR}	µg/l	9100	23	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C10 - C12 _{EH_1D_AR_#1_#2_MS}	µg/l	4100	640	690	710	440	350	320	92	85
TPH-CWG - Aromatic >C12 - C16 _{EH_1D_AR_#1_#2_MS}	µg/l	2700	400	1300	1300	770	760	620	270	210
TPH-CWG - Aromatic >C16 - C21 _{EH_1D_AR_#1_#2_MS}	µg/l	320	130	1000	850	600	520	480	180	140
TPH-CWG - Aromatic >C21 - C35 _{EH_1D_AR_#1_#2_MS}	µg/l	< 10	< 10	200	130	280	230	220	73	36
TPH Total C5 - C40 _{EH+HS_1D_TOTAL_#1_#2_MS}	µg/l			3200	3000	2100	1900	1600	610	470
VOCs										
Trichloromethane	µg/l		< 1.0	< 1.0	< 1.0	10	18	67	< 1.0	< 1.0
SVOCs										
Aniline	µg/l		21	8.8	9.9	12	16	15	2.6	1.3
2,4-Dimethylphenol	µg/l		23	< 0.05	< 0.05	8.2	8.9	7.6	< 0.05	< 0.05
2-Methylnaphthalene	µg/l		< 0.05	20	20	9.9	9.3	12	7.4	6.3
Acenaphthylene	µg/l	1.2	4.3	1.0	0.97	0.77	0.93	0.98	0.34	0.23
Acenaphthene	µg/l	12	180	70	51	36	37	38	24	19
Dibenzofuran	µg/l		110	41	33	21	20	22	14	11
Carbazole	µg/l		40	30	21	14	17	19	9	7.8
Anthraquinone	µg/l		49	9.1	9.9	13	14	19	3.8	2.7

Table 3b: S/S Trial Batch Leachability Results (higher CN impacted soil mixes)
(Only determinants with any results above LoD presented)

above
baseline

Sample Reference		Baseline Batch (TP816)	Mix 5 6h	Mix 5 1d	Mix 5 2.25d	Mix 5 4d	Mix 5 9d	Mix 5 16d	Mix 5 36d	Mix 5 64d
Analytical Parameter (Leachate Analysis)	Units									
General Inorganics										
pH (automated)	pH Units		11.3	11.7	11.7	11.9	11.9	12	12.2	12.2
Electrical Conductivity	µS/cm		390	700	790	1400	1900	1700	2700	2600
Total Cyanide (Low Level 1 µg/l)	µg/l	340	< 1.0	5.6	12	23	35	27	65	61
Complex Cyanide (Low Level)	µg/l	330	< 1.0	5.6	12	21	35	25	63	61
Free Cyanide (Low Level 1 µg/l)	µg/l	8	< 1	< 1	< 1	2	< 1	2	2	< 1
Sulphate as SO ₄	mg/l		2.7	6.7	7.9	9.9	17.2	12.7	22.6	21.4
Chloride	mg/l		3.3	3.7	3.5	3.9	6.6	5.4	7.6	6.6
Total Phenols										
Total Phenols (monohydric)	µg/l	4.7	9.3	8.7	6.5	< 1.0	< 1.0	< 1.0	4.8	2.4
Speciated PAHs										
Heavy Metals / Metalloids										
Arsenic (dissolved)	µg/l	8.5	1.2	< 1.0	5.1	< 1.0	< 1.0	3.6	< 1.0	< 1.0
Cadmium (dissolved)	µg/l	0.26	< 0.08	< 0.08	< 0.08	0.08	< 0.08	< 0.08	< 0.08	< 0.08
Chromium (dissolved)	µg/l	1.9	1.9	1.7	1.7	2.4	3.2	2.3	3.1	2.7
Copper (dissolved)	µg/l	7.1	8.6	7.4	9.8	7.4	17	15	25	30
Lead (dissolved)	µg/l	10	3.5	5.4	4.5	4.8	5.9	4.8	6.4	8.6
Nickel (dissolved)	µg/l	5.0	3.6	4.2	5.7	4.3	7.9	7.8	12	13
Selenium (dissolved)	µg/l	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	9.5
Zinc (dissolved)	µg/l	8.6	10	5.1	12	4.4	4.9	9.1	5.7	7.3
Calcium (dissolved)	mg/l		92	120	120	120	190	230	320	250
Monoaromatics & Oxygenates										
Petroleum Hydrocarbons										
VOCs										
SVOCs										

Table 4a: Summary of S/S Trial Tank Test Results - Mix 5 (lower CN impacted soil mix)
(Only determinants with any results above LoD presented)
above baseline

Sample Reference		Baseline Batch (TP813)	Baseline Batch (TP814)	Mix 14 6h	Mix 14 1d	Mix 14 2.25d	Mix 14 4d	Mix 14 9d	Mix 14 16d	Mix 14 36d	Mix 14 64d
Analytical Parameter (Leachate Analysis)	Units										
General Inorganics											
pH (automated)	pH Units	7.5		10.8	11.2	11.1	11.3	11.4	11.6	11.7	11.5
Electrical Conductivity	µS/cm			170	280	260	350	540	680	760	770
Total Cyanide (Low Level 1 µg/l)	µg/l	17000	11000	220	1100	470	1000	1900	3200	2600	5300
Complex Cyanide (Low Level)	µg/l		10000	220	1100	440	1000	1900	2700	2600	5200
Free Cyanide (Low Level 1 µg/l)	µg/l		500	2	10	27	< 1	< 1	430	< 1	86
Sulphate as SO ₄	mg/l			8.1	13.6	12.4	29.1	45.1	75	11.3	92.7
Chloride	mg/l			9.5	10	12	14	25	33	31	40
Total Phenols											
Total Phenols (monohydric)	µg/l	3000	67	1.6	1.5	7.5	7.1	11	6.1	8.7	9
Speciated PAHs											
Naphthalene	µg/l	3100	< 0.01	4.6	8.1	6.7	9.7	16	20	16	19
Acenaphthylene	µg/l	1.2	4.3	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.16	< 0.01	0.27
Acenaphthene	µg/l	12	180	2.5	4.6	3.8	4.5	7.4	8.7	8	7.3
Fluorene	µg/l	5.9	53	0.95	1.9	1.7	2.1	3	3.7	3.3	2.7
Phenanthrene	µg/l	< 0.01	< 0.01	0.75	1.5	1.3	1.9	2.1	2.8	3.2	2.4
Anthracene	µg/l	< 0.01	< 0.01	< 0.01	0.34	0.33	0.2	0.63	0.85	0.57	0.46
Fluoranthene	µg/l	< 0.01	3.9	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.37	0.46	< 0.01
Pyrene	µg/l	< 0.01	1.6	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.17	0.26	< 0.01
Total PAH											
Total EPA-16 PAHs	µg/l	3200	240	8.8	16	14	18	29	37	31	33
Heavy Metals / Metalloids											
Arsenic (dissolved)	µg/l	16	9.3	3.2	6.3	6.4	15	34	41	47	62
Cadmium (dissolved)	µg/l	< 0.08	0.21	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08	< 0.08
Chromium (dissolved)	µg/l	1.0	1.1	0.9	1.1	0.4	1.3	0.8	1.3	1.3	1.4
Copper (dissolved)	µg/l	18	< 0.7	26	15	20	30	46	71	97	130
Lead (dissolved)	µg/l	4.4	6.5	5.2	4.8	5.1	4.3	3.3	2.5	10	3.4
Nickel (dissolved)	µg/l	2.6	2.6	5	2.8	4.1	4.9	6.2	5.8	6.3	5.4
Selenium (dissolved)	µg/l	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	9.4
Zinc (dissolved)	µg/l	4.8	3.8	9.8	7.6	6.9	5	5.5	11	34	7.2
Calcium (dissolved)	mg/l			15	31	26	35	65	82	77	98
Monoaromatics & Oxygenates											
Benzene	µg/l	7500	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Toluene	µg/l	11000	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Ethylbenzene	µg/l	780	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
p & m-xylene	µg/l	5300	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
o-xylene	µg/l	2400	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Petroleum Hydrocarbons											

TPH-CWG - Aromatic >C5 - C7 _{HS_1D_AR}	µg/l	7500	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C7 - C8 _{HS_1D_AR}	µg/l	11000	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C8 - C10 _{HS_1D_AR}	µg/l	9100	23	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
TPH-CWG - Aromatic >C10 - C12 _{EH_1D_AR_#1_#2_MS}	µg/l	4100	640	26	35	21	65	70	72	16	70
TPH-CWG - Aromatic >C12 - C16 _{EH_1D_AR_#1_#2_MS}	µg/l	2700	400	60	80	24	98	200	170	140	190
TPH-CWG - Aromatic >C16 - C21 _{EH_1D_AR_#1_#2_MS}	µg/l	320	130	110	120	12	97	190	150	170	200
TPH-CWG - Aromatic >C21 - C35 _{EH_1D_AR_#1_#2_MS}	µg/l	< 10	< 10	< 10	< 10	< 10	< 10	98	< 10	46	90
TPH Total C5 - C40 _{EH+HS_1D_TOTAL_#1_#2_MS}	µg/l			190	240	57	260	560	400	370	550
VOCs											
1,3,5-Trimethylbenzene	µg/l		7.4	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
1,2,4-Trimethylbenzene	µg/l		16	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
SVOCs											
Aniline	µg/l		21	2.9	3.9	2.8	4.2	9.9	11	5.7	23
2,4-Dimethylphenol	µg/l		23	0.47	0.54	0.46	< 0.05	1.7	< 0.05	1.2	< 0.05
2-Methylnaphthalene	µg/l		< 0.05	1.1	2	1.8	2.3	3.1	3.3	3.5	3
Dibenzofuran	µg/l		110	1.5	2.8	2.6	3	4.4	5.6	5.4	4.2
Phenanthrene	µg/l	< 0.01	< 0.01	0.75	1.5	1.3	1.9	2.1	2.8	3.2	2.4
Anthracene	µg/l	< 0.01	< 0.01	< 0.01	0.34	0.33	0.2	0.63	0.85	0.57	0.46
Carbazole	µg/l		40	0.63	1.1	1.1	2	3.4	5.6	7.1	7.6
Anthraquinone	µg/l		49	< 0.05	0.74	0.56	1	1.8	2.4	4.1	3.9
Fluoranthene	µg/l	< 0.01	3.9	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.37	0.46	< 0.01
Pyrene	µg/l	< 0.01	1.6	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	0.17	0.26	< 0.01

Table 4b: Summary of S/S Trial Tank Test Results - Mix 14 (higher CN impacted soil mix)
(Only determinants with any results above LoD presented)

above baseline

Phenols were significantly reduced with all typical OPC/GGBS/QL mixes, with addition of the GAC showing the largest reduction. These mixes also had the best impact on reducing Naphthalene. The lighter end TPH aromatics' leachability was significantly reduced, again with the addition of the GAC seemingly having a marked beneficial effect on the C10-C12 range. The results for the C16-C21 range were disappointing and is probably due to the high CN concentrations affecting the generation of sufficient hydration complexes within the matrix.

Tank tests

In addition to the batch leachate testing, mix 5 and mix 14 (low CN impacted soils and high CN impacted soils, respectively) were selected for tank testing, in accordance with the EA NEN 7375:2004 standard test method, to provide an indication of the potential reduction in the level of leachability that might be expected from this test as compared to the more aggressive batch test. These were two standard hydraulic binder systems that could be practicably used in the full-scale works. Mix 5 showed some potential to achieve an acceptable level of performance. It was also of interest to assess the level of reduction that could be possible with Mix 14 on high CN impacted soil hotspots.

The 64d results for Mix 5 on the lower CN impacted materials were acceptable, with only the amphoteric behaviour of some of the metals again generating higher leachate concentrations. This mix should also be able to target higher concentrations of TPH present across the site.

Although greatly reduced from the batch leachate test result, CN was still high, with a concentration of 5,300ug/l at 64d. This would be expected to be the case for a hydraulic binder. However, the result does highlight the reduction possible with the much less aggressive test method, which can be used to assess likely reductions across all the mixes used in the study. Most PAHs were reduced, with the exception of Phenanthrene and Anthracene. All the TPH aromatics were greatly reduced which provides a good indication of the likely performance of Mix 5 on higher TPH concentrations.

5 Discussion and Conclusions

Cement-based fixation and encapsulation additives have been used successfully for many years for the immobilisation of contaminants, particularly within soils and sludges. Most of this success is based on results of treatability studies in developing suitable treatment mix designs, which are usually conducted over short time periods, typically from 28 to 42 days after treatment.

The main concern regarding the long-term behaviour of S/S treated material, is the environmental impact that may occur should a treated material 'fail'. Failure will be related to the dominant deterioration mechanisms prevailing at the service location and the variation in pH conditions of the system, in particular, the impact on the leachability of metal complexes.

The environmental impact, due to the deterioration of the material could be in the form of vapour, or particulate emissions and/or leachates. The degree of impact will depend on the pathway and receptor. Therefore, treatment specifications for S/S material are now generally based on probabilistic risk assessments. Even considering the variance in treatment performance demonstrated, the leachate results generated by the mixes trialled in this study provide an indication of the level of treatment performance possible with the most highly contaminated soil hotspots on the Manox site.

It is vital to identify and understand the potentially destructive mechanisms that could affect the long-term performance of the S/S material at a site. 'Intrinsic' actions are as a result of poor workmanship, poor design, reactions between waste components and binders and reactions between different waste components. 'Extrinsic' actions, which include physical and chemical weathering, mechanical damage, biological attack and attack by aggressive water, are as a result of the final environmental exposure conditions. It is a widely held view that the presence of organic contaminants can have a detrimental impact on the hydration of Portland cement. However, provided such effects can be controlled to acceptable limits, the fact that contaminants are immobilised by various mechanisms as the materials undergo hydration and their leaching potential is reduced, can provide the required degree of treatment for the final service environment.

In addition to the above mechanisms, macro-encapsulation of contaminants will also occur. This is where contaminants are physically entrapped in the discontinuous pores within the larger structural matrix of the solidified material. This aspect of the immobilisation is mainly dependent on the physical integrity of the S/S material. The tank leachate testing of monolithic samples have generally demonstrated a good level of reduction in leachable concentrations, as compared to standard batch tests on the same materials.

Treatability studies, using the contaminated source materials from the site, although conducted over a relatively short time scale, are enough to understand the behaviour of the mixes and eliminate the potential for failures following full-scale treatment works. A fundamental aspect of the testing regime is that worst-case leachate testing has been undertaken on the treated materials, as the sample

preparation involved a reduction in the particle size/structure of the S/S samples, thus eliminating the macroencapsulation aspect of the treatment and so relying solely on chemical fixation processes at the microencapsulation level. This is beneficial in understanding potential longer-term behaviour should weathering effects impact on the materials in the near surface ground. Particle reduction seeks to simulate more extreme effects of mechanisms, such as carbonation, sulphate attack and freeze-thaw, which might reduce the physical integrity of the material depending on severity. This, therefore, provides an understanding of the effects of worst-case leaching potential. As data from most on-site studies is only available for a maximum of 20 to 30 years, reliance is placed on the results of modelling in order to provide confidence in the much longer-term performance. Further information on the results of such studies is provided in the references listed in Appendix C.

This study has shown there to be enough general reduction potential in the leachability of the worst case, although on the lower CN impacted materials present within the source soils, to be able to confirm that there are a number of suitable hydraulic binder system designs that can be used to achieve significant leachability performance, albeit with some modifications to mix designs presented here. It should also be noted that the study has confirmed that the use of the technique will improve the visual and olfactory nature of the most impacted materials likely to be present at the site.

The very high CN impacted soil hotspots would need a separate assessment of mix design based on the results presented here. However, all the worst case higher CN impacted materials only represents about 4% of the total soils to be treated using S/S across the site. Therefore, we would need to carry out an additional study on samples that represent the majority of soils to be treated in the full-scale works in order to confirm the most suitable mix design. The results presented here would suggest there is likely to be 3no, mix designs adopted:-

Mix 1. Hydraulic binder system for 96% of materials to be treated

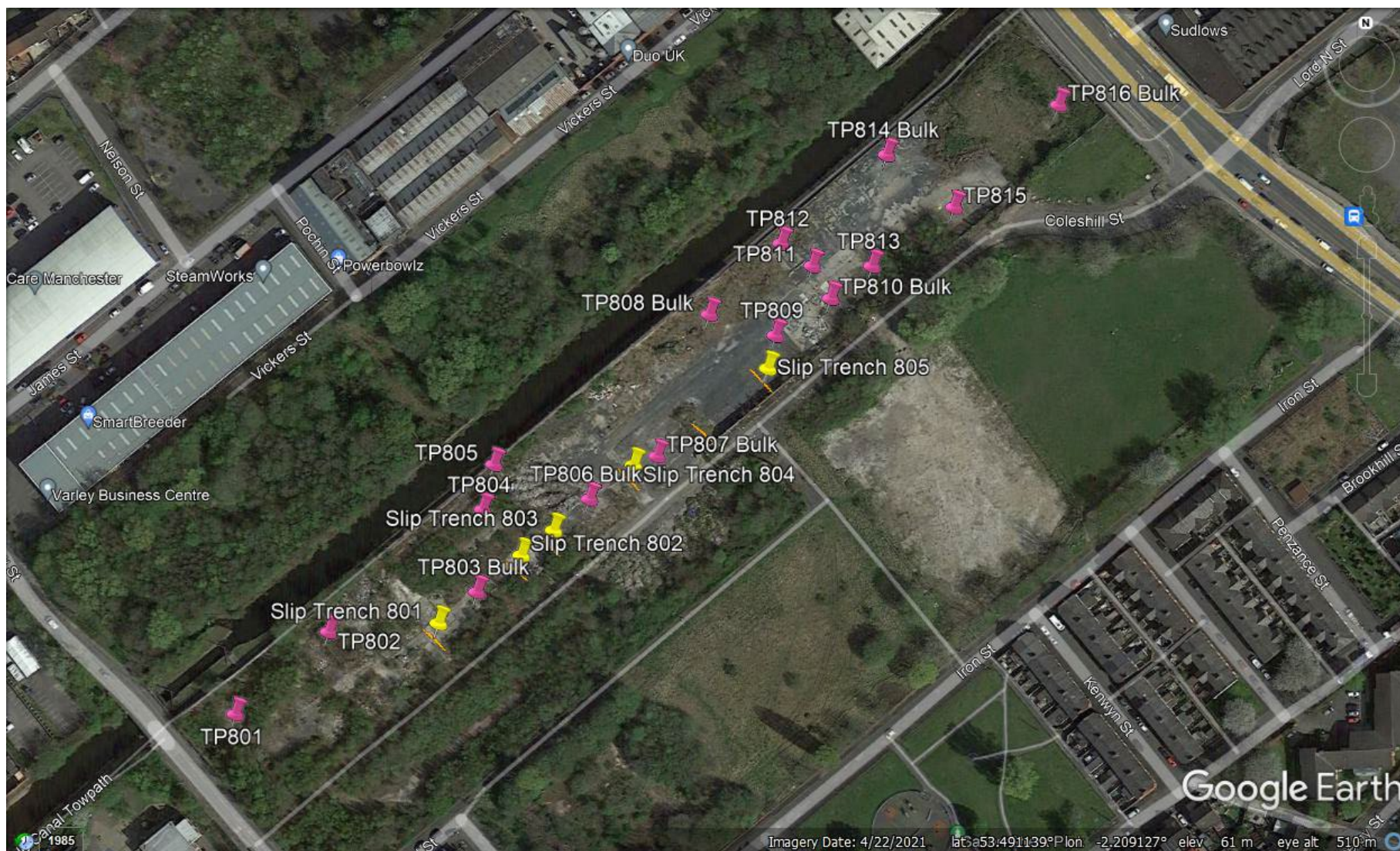
Mix 2. Hydraulic binder system for circa 2% (lower CN impacted) materials to be treated

Mix 3. Combination system for circa 2% (very high CN impacted) materials to be treated.

We hope that this report provides the required level of information needed to demonstrate the suitability and potential effectiveness of S/S treatment approach for the most impacted soils at the site.

APPENDIX A

TRIAL PIT LOCATION PLAN



Trial Pit Sampling Locations

APPENDIX B

LABORATORY TEST REPORT CERTIFICATES

APPENDIX C

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